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AD-A236 418

ARE TM (UHR) 91305

FEBRUARY 1991

COPY No 33

ARE TM (UHR) 91305

COMPONENT LOCAL VELOCITIES OF A SHIP ALONG A DEFINED AXIS

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ADMIRALTY RESEARCH ESTABLISHMENT

Procurement Executive Ministry of Defence

Haslar GOSPORT Hants PO12 2AG

UNLIMITED

CONDITIONS OF RELEASE

0096210 300556

.... DRIC U

.... DRIC Y

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1. OBJECTIVE

Enhancements to the PAT-86 suite of ship motion computer programs are anticipated shortly. One addition will be an option that calculates the local RMS motions when viewed along a defined axis.

This technical memorandum records the theory involved and its subsequent inclusion into PAT-91. An example is also shown.

2. INTRODUCTION

The PAT suite of seakeeping computer programs was first implemented in 1980. PAT-86 (Reference 1) is the version of the suite currently in use at ARE Haslar and it is intended that this will be superseded by PAT-91. This will include several minor enhancements which will be described in a forthcoming User Guide. One option which will be included in the updated version will be to calculate the local velocities along an arbitrary defined axis.

As a ship passes through waves it responds in six rigid body modes (surge, sway, heave, roll, pitch and yaw). Five of these, (surge is neglected), are calculated in the PAT suite; heave and pitch are referred to as the vertical plane motions. Sway, roll and yaw are lateral plane motions. These rigid body motions are superimposed on one another leading to a total compound motion at any point on the ship.

Furthermore, these total compound motions can be combined and translated to form motions along an arbitrarily specified axis.

This work has been carried out under Entity Code RE005266 and Package 15e.

3. MOTIONS ALONG A DEFINED AXIS

Figure 1 shows a ship advancing with constant forward speed, with axes X_1, X_2, X_3 whose origin is at point P. The basic hull data are shown in Table 1.

Consider an independent axis X_c defined by two variables υ and ψ where

> ψ is the bearing of the axis relative to the centreline of the ship (from stern to bow). Positive anticlockwise.
>
> υ is the elevation of the axis relative to the calm water surface (positive above surface, negative below surface).

The velocities along X_c consist of components of velocities along the three axes X_1, X_2, X_3 with

$\dot{x}_1$ - Absolute forward velocity
(Effect of pitch and yaw: surge is neglected)

$\dot{x}_2$ - Absolute vertical velocity
(Effect of heave, pitch and roll)

$\dot{x}_3$ - Absolute lateral velocity
(Effect of sway, roll and yaw)

and the resultant velocity along the defined direction is given by

$$\dot{x}_c = \dot{x}_1 Cos\psi Cos\upsilon - \dot{x}_2 Sin\psi Cos\upsilon + \dot{x}_3 Sin\upsilon \tag{1}$$

Only velocity changes will be considered in this study (ie the effect of forward speed is neglected). Acceleratons can be easily calculated.

4. RESULTS

The theory in Section 3 has been implemented in PAT-91 and examples are shown. A calculation was carried out with a ship travelling at 20 knots in sea state 7. Details of the points where the total motion calculations were carried out are given in Table 2.

Figure 2 shows how RMS velocity changes with axis bearing ψ for a fixed elevation υ = 0.0 degrees. The position of interest is on the centreline of a ship travelling at 20 knots in beam and head seas. The motions are symmetrical about a bearing of 180 degrees as would be expected, since point P is on the centreline. Roll is the predominant motion in beam seas, so the maximum motions are experienced at bearings of 90.0 and 270.0 degrees. However, in head seas pitch is the predominant motion and so maximum motions are experienced at bearings of 0 and 180 degrees. The difference in magnitudes of the velocities experienced in beam and head seas is due to the roll amplitude being about twice that of the pitch amplitude (generally speaking).

Figures 3-5 show results obtained in stern quartering seas. Figure 3 shows the RMS velocity of a point off the centreline (1.0 m to starboard). The motions are not symmetrical and the maximum velocity occurs at a bearing of about 270 degrees. Figure 4 shows how the RMS velocities vary with elevation for a fixed bearing (ψ = 30.0 degrees). The point of interest is not on the centreline so a symmetrical curve was not expected. However, Figure 4(b) shows the same data plotted in the conventional style and the curve is approximately antisymmetric about a 0 degree elevation angle. This is because components of the motions from the X_1 and X_2 directions are small when compared with the components of the motions in the X_3 directions (small bearing angle).

Figure 5 shows how the RMS motion varies along the ship length for two different elevation angles and a given bearing. More motion is observed for larger angles of elevation. This is probably due to the fact that for stern quartering waves the dominant term is due to heave and pitch. The

curve becomes less linear as the elevation angle increases due to the increasing contribution from the pitch component.

5. CONCLUSIONS

This technical memorandum has outlined a method of calculating the component local velocities along a given axis when the ship is travelling at forward speed in long crested waves.

The results as presented appear reasonable and illustrate expected trends. The TM only considered RMS velocities along an axis and did not consider motions perpendicular to the defined axis.

The PAT suite neglects surge. This means that the translation velocity, the $\dot{x}_1$ component, may be inaccurate especially in following seas.

6. FURTHER WORK

Further enhancements can be made depending upon the needs of the customer. Suggestions are as follows:

a. Define a set of orthogonal axes, so motions along and perpendicular to a defined axis can be determined.

b. Use the results to generate time histories of the observed motions.

c. Investigate points of interest on the ship at which motions along an axis are maximised or minimised.

REFERENCES

1. P R Loader, R N Andrew. User Guide for the PAT-86 Suite of Ship Motion Computer Programs. ARE TM(UHR)86301. January 1986. UNCLASSIFIED.

Table 1

BASIC HULL DATA

Displacement	=	4340.0 tonnes
Length	=	123.4 metres
Beam	=	15.2 metres
Draught	=	4.8 metres
LCG abaft of midships	=	2.5 metres
VCG above USK	=	5.5 metres
HCG above waterline	=	0.8 metres
Yaw radius of gyration/length	=	0.225
Roll radius of gyration/beam	=	0.391

Table 2

RUN CONDITIONS

$H_{1/3}$ = 8.0 metres

T_0 = 13.0 seconds

Speed = 20.0 Knots

Figure Number	X (Station)	Y (m) Stbd from CL	Z (m) up from USK	Heading (Degrees)
2	10	0.0	6.0	90.0
3	10	1.0	10.0	75.0
4	10	1.0	10.0	75.0
5	1-21	0.0	6.0	75.0

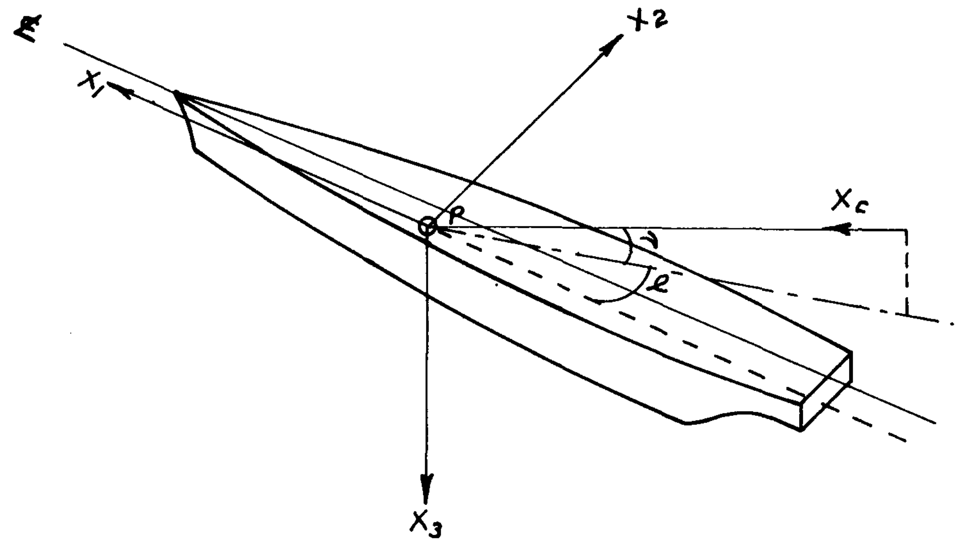

FIG. 1. COORDINATE SYSTEM

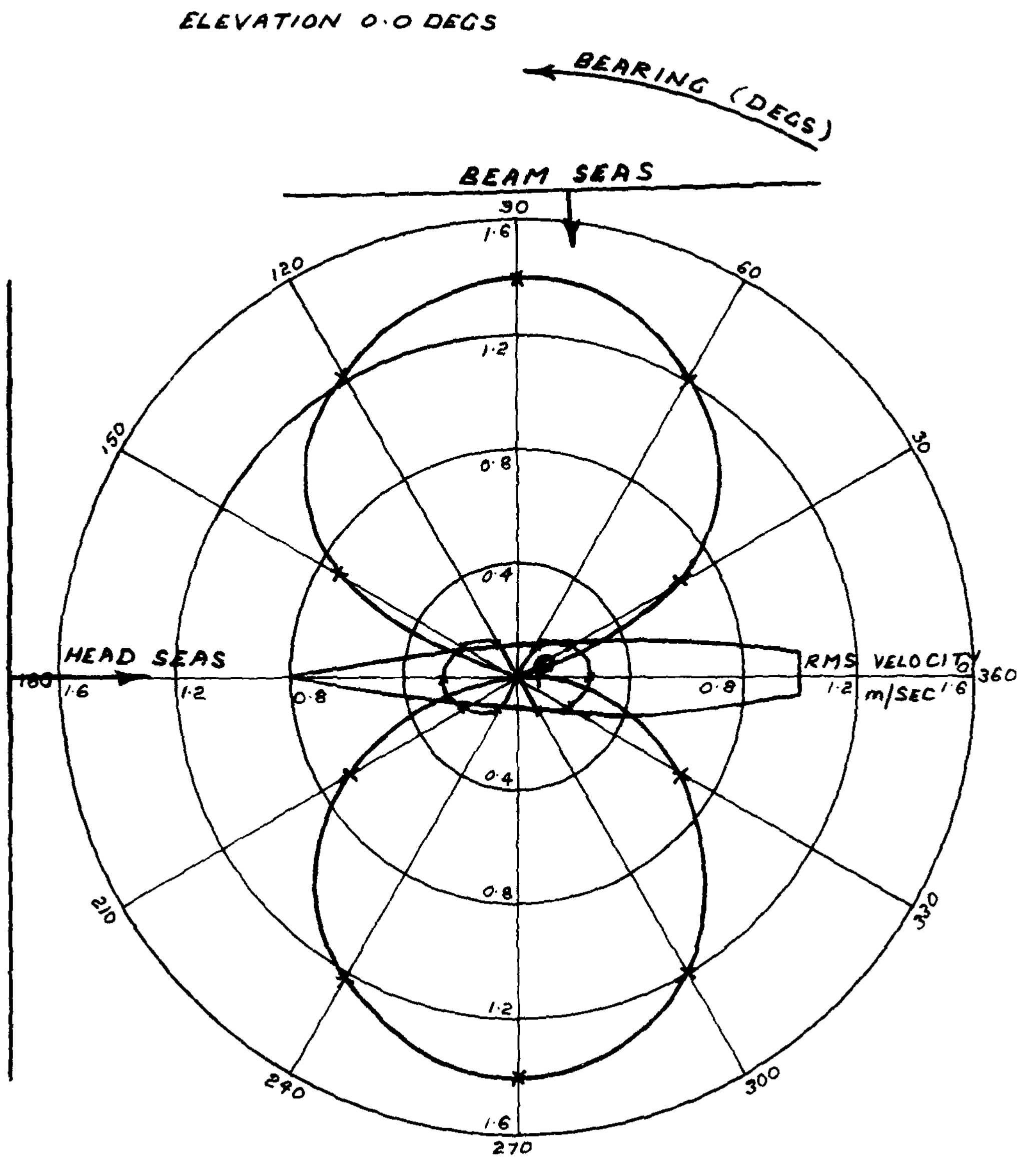

FIG. 2. VARIATION IN LOCAL VELOCITY WITH BEARING

ELEVATION 70 DEGS

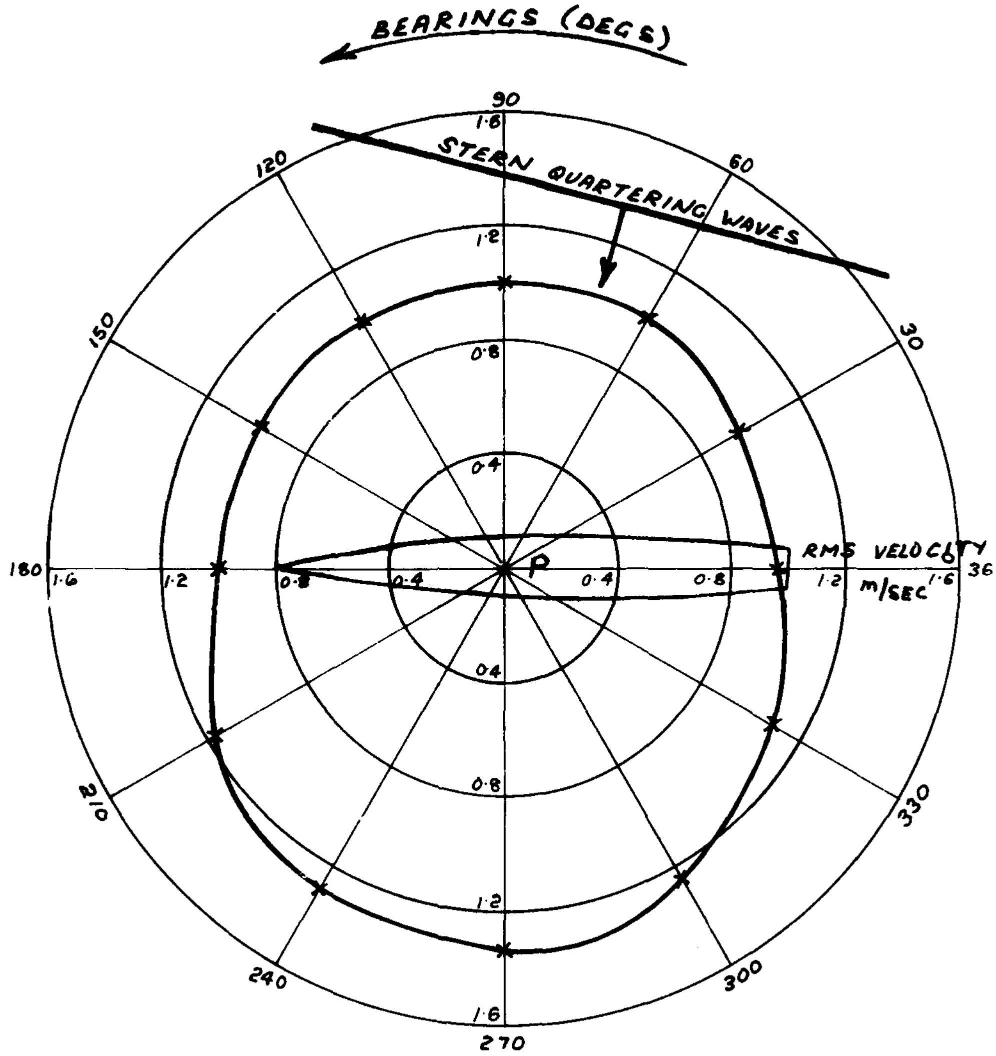

FIG. 3. VARIATION IN LOCAL VELOCITY WITH BEARING

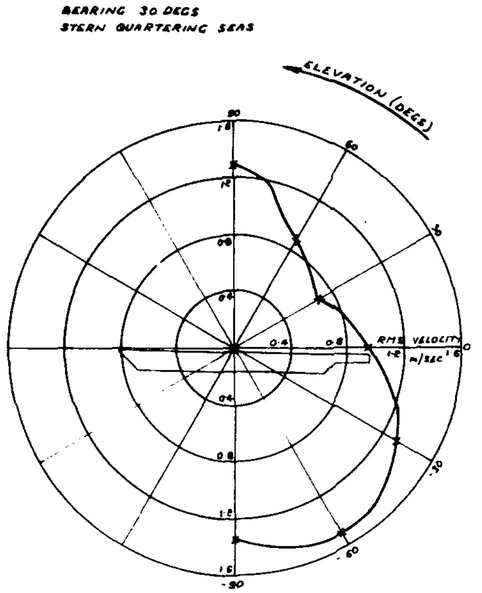

FIG 4(a) POLAR CO-ORDINATES

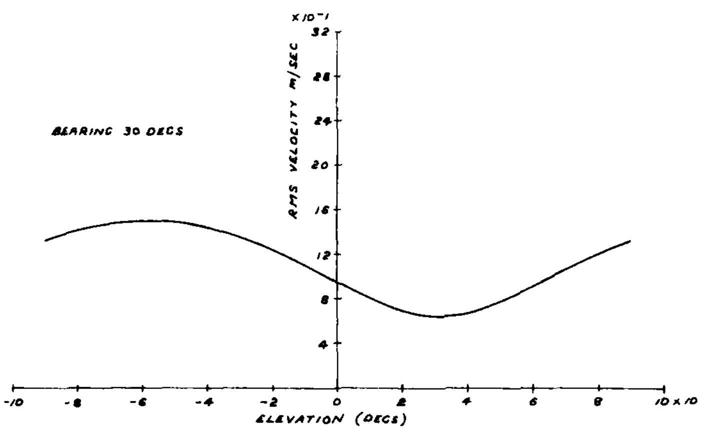

FIG. 4(b). CARTESIAN CO-ORDINATES

Figure 4

VARIATION IN LOCAL VELOCITY WITH ELEVATION

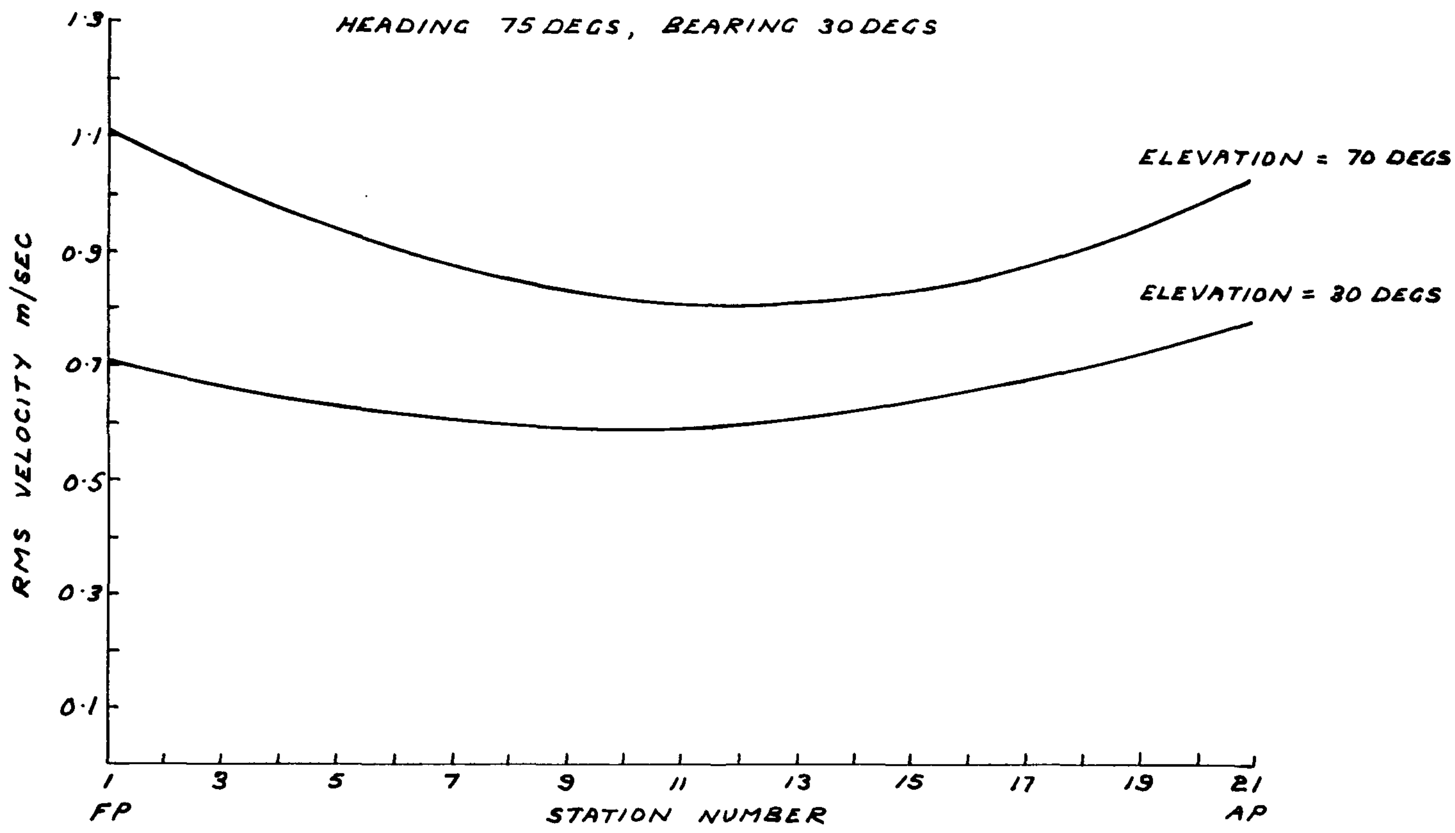

FIG. 5. VARIATION IN LOCAL VELOCITY COMPONENT ALONG LENGTH OF SHIP

REPORT DOCUMENTATION PAGE

DRIC Reference number (if known)

Overall security classification of sheet UNLIMITED

(As far as possible this sheet should contain only unclassified information. If it is necessary to enter classified information, the field concerned must be marked to indicate the classification, eg (R), (C) or (S).

Originator's Reference/Report No	ARE TM(UHR)91305
Month	FEBRUARY
Year	1991
Originator's Name and Location	ADMIRALTY RESEARCH ESTABLISHMENT HASLAR GOSPORT HANTS PO12 2AG
Monitoring Agency Name and Location	
Title	COMPONENT LOCAL VELOCITIES OF A SHIP ALONG A DEFINED AXIS
Report Security Classification	UNLIMITED
Title Classification (U, R, C or S)	
Foreign Language Title (In the case of translations)	
Conference Details	
Agency Reference	
Contract Number and Period	
Project Number	
Other References	
Authors	P CROSSLAND A R J M LLOYD
Pagination and Ref	
Abstract	
Abstract Classification (U, R, C or S)	
Descriptors	SHIP MOTION THEORY
Distribution Statement (Enter any limitations on the distribution of the document)	